1D and 2D Two Pion Correlations

Results from EG2 experiment

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Introduction

Bose-Einstein Correlation (BEC) arise from the interference between the symmetrized wave functions of identical bosons, in this case pions.
Using BEC it is possible to obtain information about the particle source or the emission duration

Experimental definition

Experimentally, the correlation is calculated using pion pair distribution and a background distribution $D_b(p_1, p_2)$ that doesn't have BEC correlations. The correlation function in this analysis is defined:

$$R(p_1, p_2) = \frac{D(p_1, p_2)}{D_b(p_1, p_2)} \tag{1}$$

Where p_i are the pion 4-momentum and D are the probability density from two particles.

Results from other experiments

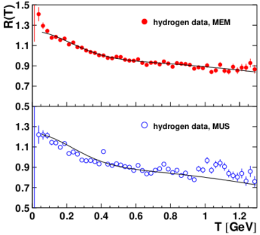


Fig. 4. Double ratio correlation function for like-sign hadron pairs obtained with *MEM* and *MUS* based on hydrogen target data.

HERMES

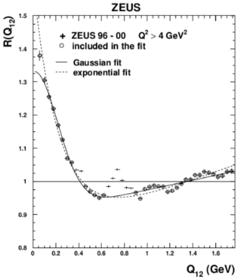


Figure 2: *The measured Bose-Einstein correlation function, $R(Q_{12})$, together with the Gaussian and the exponential fits. The error bars show the statistical uncertainties. The data points included in the fit are marked with the circles.*

ZEUS

Results from other experiments

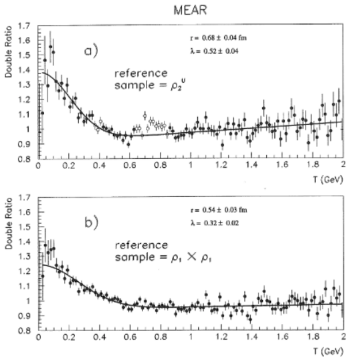


Figure 6.14: Double ratio $R'(T) = R^{\text{data}}(T)/R^{\text{MC}}(T)$ for $R(T) = \rho_2(T)/\rho_2^u(T)$ in (a) and for $R(T) = \rho_2(T)/\rho_1 \otimes \rho_1(T)$ in (b), here displayed as function of the variable $T = \sqrt{M^2 - 4m_\pi^2}$ The fitted values for r and λ corresponds to the "Goldhaber Parameterization" 2.16.

H1

Pions selection

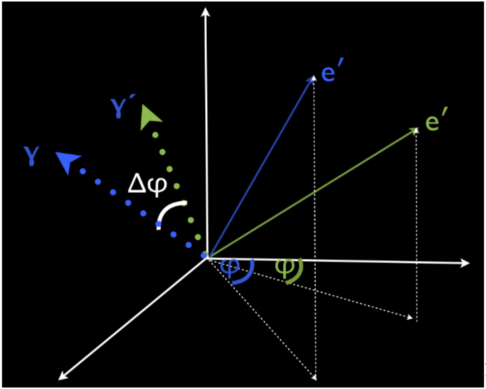
Pions are identified using time of flight cuts for different momentum ranges. Pions pairs are selected from events with at least 2 positive pions.
Final results are presented for four different targets:

- Deuterium
- Carbon
- Iron
- Lead

Background distribution (Mixed event method)

Pions pairs for the background distribution are created taking random positive pions from two different events with at least 2 pions.
We have to conserve collinearity of the virtual photon from these two different events. To achieve this, the momenta of particles in the second event is rotated to align both virtual photons.
For both, same event and mixed event pairs, $Q_{12} = \sqrt{-(p_1 - p_2)^2}$ is calculated.

Correlation Function

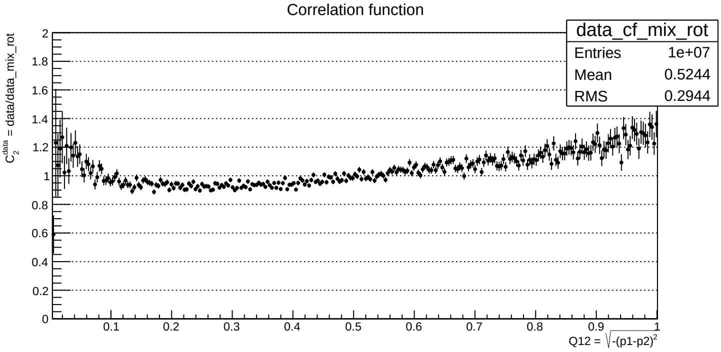


[1]

[1] Hadronization Studies via pi 0 Electroproduction off D, C, Fe, and Pb, Taisiya Mineeva (2013).

Correlation Function

Correlation function for Carbon Target.



Double Ratio correction

Dividing correlation function from the data by the one obtained from simulations which no contains BEC, we expect to reduce biases from geometrical acceptance, close track efficiency[2] and kinematical cuts.
Double ratio is defined:

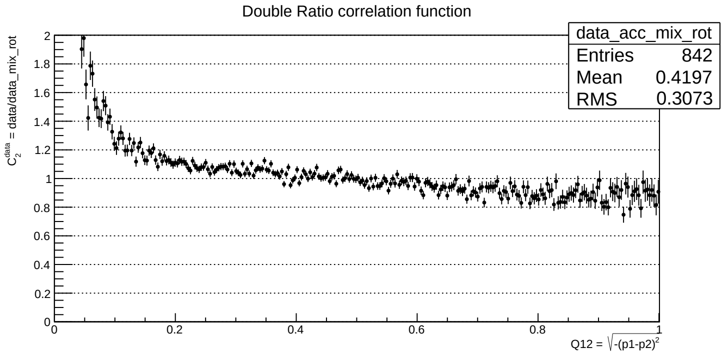
$$R(Q_{12}) = R(Q_{12})^{data} / R(Q_{12})^{simul} \tag{2}$$

$$R(Q_{12}) = (same/mixed)^{data} / (same/mixed)^{simul} \tag{3}$$

[2] Studied by Mikhailov,Stavinsky, Vlassov in Methods for Close -Track efficiency study and its applications for CLAS

Double Ratio correlation function

Double ratio correlation function for Carbon Target.



Goldhaber parametrization

The correlation function R can be parametrized using:

$$R(Q_{12}) = 1 + \lambda exp(-r^2 Q_{12}^2) \tag{4}$$

This parametrization corresponds to a Gaussian shape of a particle source distribution of size r in the center of mass of the pair. Where the parameter λ corresponds to a coherence (or chaoticity) factor. Complete coherent sources lead to no correlations ($\lambda = 0$), and complete incoherent sources lead to ($\lambda = 1$).
r is interpreted as the size of the production area of the pions.

[2] G. Goldhaber, S. Goldhaber, W. Lee, A. Pais, Phys. Rev. 120, 300 (1960).

Goldhaber Parametrization

Different modified parametrizations are used to describe long-range correlations at large Q_{12} :

$$R(Q_{12}) = \gamma(1 + \lambda exp(-r^2 Q_{12}^2)) \tag{5}$$

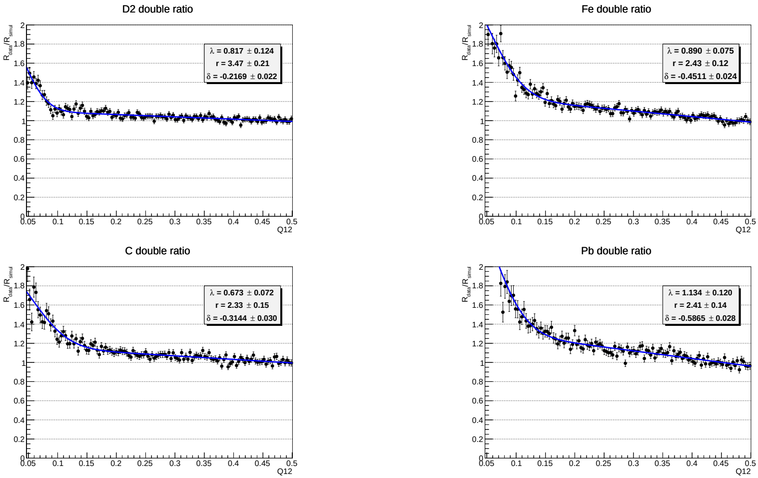
$$\boxed{R(Q_{12}) = \gamma(1 + \lambda exp(-r^2 Q_{12}^2))(1 + \delta Q_{12})} \tag{6}$$

$$R(Q_{12}) = \gamma(1 + \lambda exp(-r^2 Q_{12}^2))(1 + \delta Q_{12} + \epsilon Q_{12}^2) \tag{7}$$

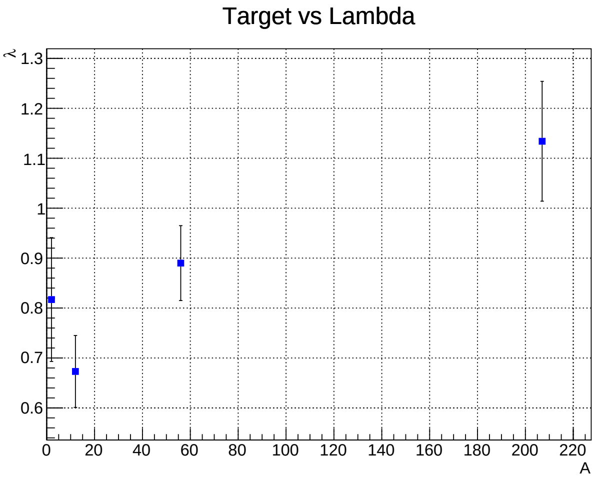
Fit is performed in the range $[0.05 - 0.50] GeV$. **Under 0.05 GeV, Coulomb effects are strong enough and extra corrections are needed.**

[2] HERMES Collaboration, arXiv:1505.03102v2

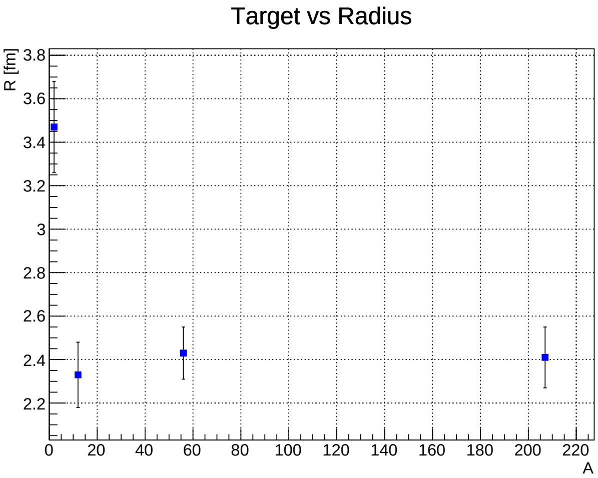
Double Ratio



Target vs Lambda Comparison



Target vs Radius comparison



2D correlation function

Correlation function can also be studied in two dimensions, in this case, the longitudinally co-moving system is used. This system is defined for each pair as the frame which the sum of momenta $p_1 + p_2$ is perpendicular with the virtual photon axis.[3]

[3] ZEUS collaboration, Phys.Lett.B583:231-246,2004

2D correlation function

The $\overrightarrow{q_{12}} = \overrightarrow{p_1} - \overrightarrow{p_2}$ variable is decomposed in q_{long} and q_{trans}
Here q_{long} corresponds to the projection along the virtual photon.
q_{trans} is the transverse component.
The two-dimensional analysis provides sensitivity to a possible elongation of the source expected in the Lund string model [4]

[4] G. Goldhaber et al., Proceedings of the Workshop on Local Equilibrium in Strong Interactions (Bad Honnef, West Germany, 1984), D.K Scott and R.M. Weiner (eds.), p. 115. World Scientific, Singapore (1985).

2D Goldhaber parametrization

The correlation function is calculated in the same way as the 1-dimensional analysis.
In this case, the parametrization used to fit the correlation corresponds to:

$$R(q_t, q_l) = \gamma(1 + \lambda exp(-(r_t^2 q_t^2 + r_l^2 q_l^2)))(1 + \beta_t q_t + \beta_l q_l) \quad (8)$$

A 2 dimensional gaussian distribution.

[4] ZEUS collaboration, Phys.Lett.B583:231-246,2004

Results from other experiments

The following values for the correlation function were obtained for $Q^2 > 110$ GeV^2:

$$
\begin{aligned}
r_T &= 0.58 \pm 0.05(\text{stat.})^{+0.03}_{-0.12}\,(\text{syst.})\ \text{fm},\\
r_L &= 0.87 \pm 0.06(\text{stat.})^{+0.09}_{-0.01}\,(\text{syst.})\ \text{fm},\\
\lambda &= 0.35 \pm 0.03(\text{stat.})^{+0.03}_{-0.05}\,(\text{syst.}).
\end{aligned}
$$

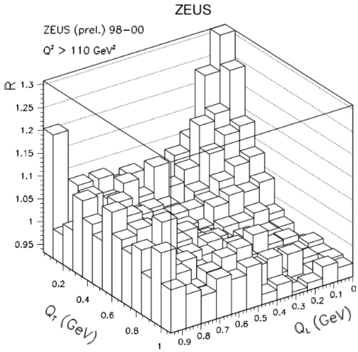
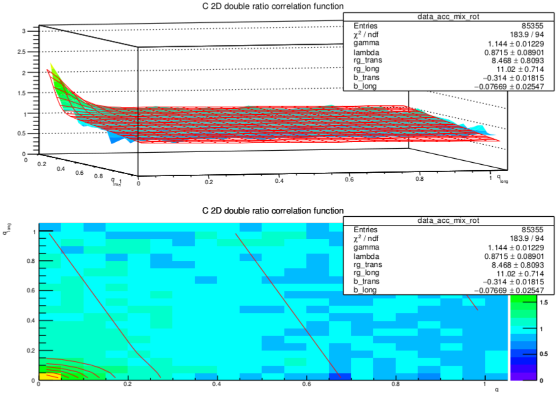


Figure 4: *The measured two-dimensional BE function $R(Q_T, Q_L)$ for $Q^2 > 110$ GeV^2.*

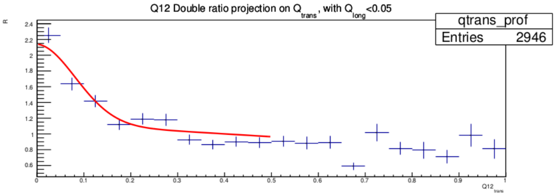
2-dimensional Double Ratio

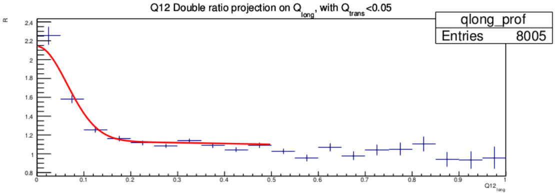
Double ratio correlation function for Carbon Target.



2-dimensional Double Ration

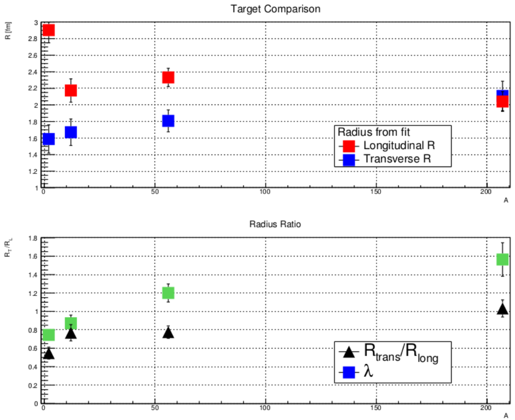
Projections on q_{trans} and q_{long}





2D parameter comparison

Parameter comparison between nuclear targets

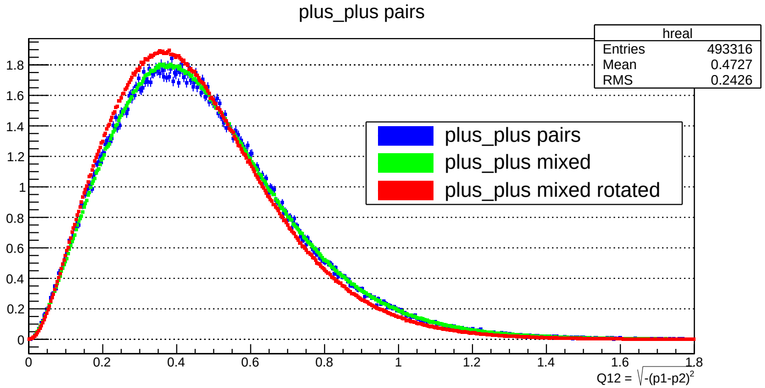


Conclusions

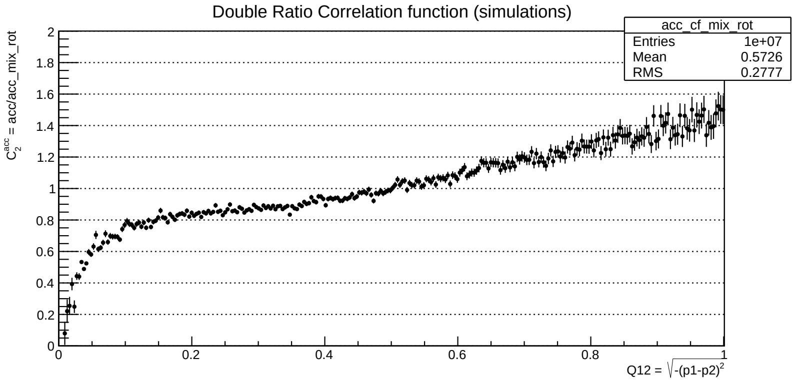
- Parameter R is independent of nuclear target for 1D correlation functions.
- Elongation along longitudinal axis ($R_{trans} < R_{long}$) is found.
- Ratio R_{trans}/R_{long} increases with nuclear target number A.
- Coherence factor (λ) increases with nuclear target number A.

Backup Slides

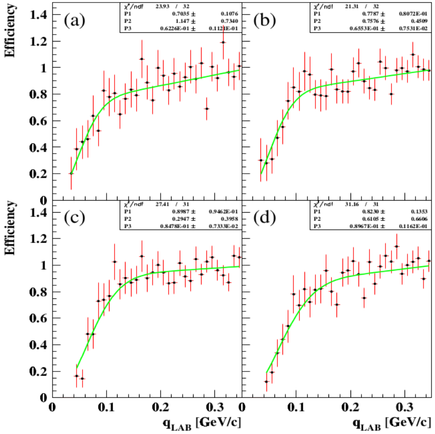
Q_{12} pair distributions



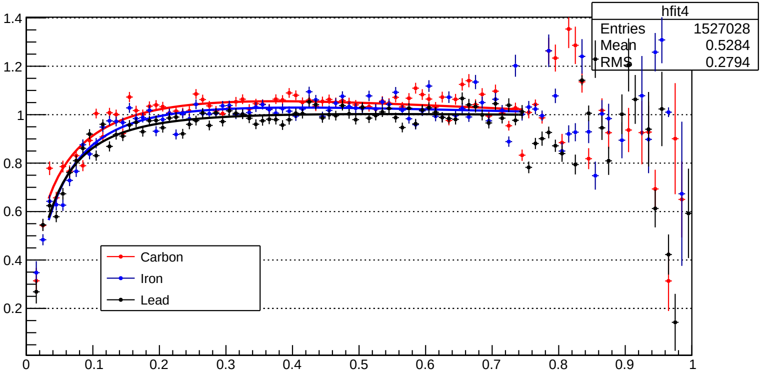
Correlation function (simulations) Carbon target



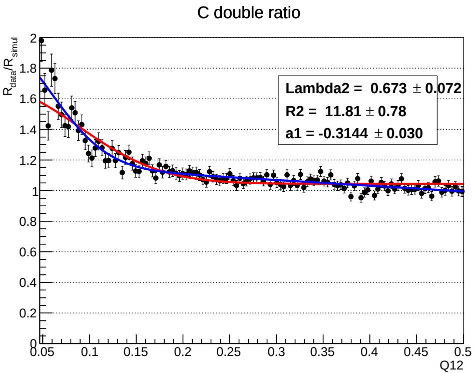
Stavinsky Close-track Efficiency



Stavinsky Close-track Efficiency



Goldhaber fit



HERMES target results 1D

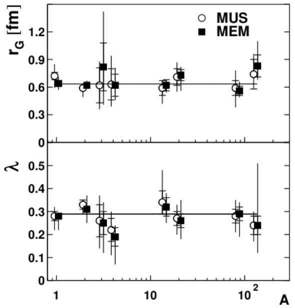


Fig. 7. The parameters r_G (top panel) and λ (bottom panel) are shown as a function of the target atomic mass A. The inner part of the error bars indicate the statistical uncertainty and the total error bars have systematic uncertainties added in quadrature. The horizontal lines correspond to the average value of the parameters.

ZEUS 2D results

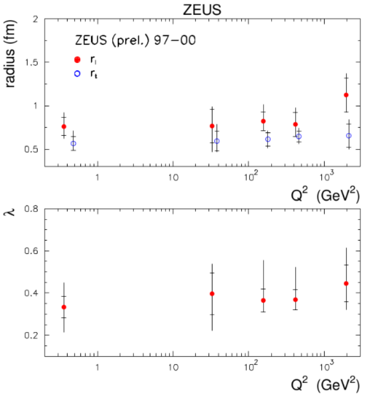


Figure 6: *The extracted radii, $(r_t,\ r_l)$, and the incoherence parameter λ as functions of Q^2 for the two-dimensional correlation function $R(Q_T, Q_L)$.*